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RESEARCH MEMORANDUM

INVESTIGATION TO MACH NUMBER 2.0 OF SHOCK-POSITIONING CONTROL SYSTEMS FOR A VARIABLE-GEOMETRY INLET IN COMBINATION WITH A J34 TURBOJET ENGINE

By L. Abbott Leissler and J. Cary Nettles

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

December 20, 1954

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

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SUMMARY

Shock-positioning controls designed to actuate the translating spike and the variable bypass of a variable-geometry inlet were investigated in the 8- by 6-foot supersonic tunnel. The operation of this inlet was observed in combination with a J34 turbojet engine at tunnel Mach numbers from 1.7 to 2.0. At Mach number 1.9, it was demonstrated that either the translating spike or the bypass could be automatically actuated to maintain the inlet terminal shock just inside the cowl lip over a range of engine mass flow. With the bypass controlled by the terminal shock and the spike translation controlled by the conical shock, the inlet was automatically maintained near critical air flow as the Mach number was varied from 2.0 to 1.75 with constant engine rotative speed.

INTRODUCTION

The control of fuel flow by inlet-shock position has been successfully applied to a ram jet (refs. 1 and 2). One control system illustrated that the relation between conical shock position and flight Mach number can be employed to maintain a preselected flight speed. Another control system for this ram jet utilized the interrelation of the terminal shock position and the diffuser performance to maintain the inlet near critical conditions. The results obtained with the ram jet were used to devise similar systems for the inlet of the turbojet engine of reference 3. One control system which was investigated at a free-stream Mach number M_0 of 1.9 was arranged so that the position of the terminal shock would automatically control the spilling of air by either the bypass or the translation of the spike. A second control system was used in conjunction with the translating spike to maintain the conical shock near the cowl lip as the stream Mach number was varied from 1.7 to 2.0.

The nacelle-mounted J34 turbojet engine equipped with both a translating spike and a variable-area bypass was investigated with automatic controls in the Lewis 8- by 6-foot supersonic tunnel. These control systems were investigated at engine rotative speeds from 80 to 100 percent of rated. The operation of these control systems is described.

SYMBOLS

The following symbols are used in this report: 3498

A_r	reference area, defined by diameter at compressor inlet, 2.41 sq ft
M	Mach number
M_D	Mach number at which conical shock intersects cowl lip
m	mass flow
N	engine rotational speed, rpm
N_r	rated engine rotational speed, 12,500 rpm
P	total pressure, abs
p	static pressure, abs
W_3	air flow rate measured at compressor face, lb/sec
δ	total pressure divided by NACA standard sea-level absolute pressure
θ	total temperature divided by NACA standard sea-level absolute temperature
θ_l	angle between axis of cone and line joining cone tip and cowl lip, deg

Subscripts:

c	cone
l	lip of cowl
0	free stream
2	ahead of bypass
3	compressor face

APPARATUS

The general layout of the J34 nacelle configuration is shown in figure 1(a). For this inlet, a combination of 17° internal cowl angle and 25° half-cone angle made it possible to contour the subsonic diffuser so that an area variation essentially equivalent to a 6° total angle cone was obtained at the forward spike position, and internal contraction did not occur at the aft spike position. The forward spike position would be a design in which the conical shock intersects the cowl lip at a Mach number of 2.4; whereas for the aft spike position the shock intersection would occur at a Mach number of 1.58. A continuous variation of spike position was obtainable with a remotely controlled screw jack mounted within the centerbody.

The bypass air was bled through the outer wall of the subsonic diffuser by a series of equally spaced longitudinal slots which opened to the cavity between the diffuser wall and the nacelle skin. The flow of bypass air was controlled by a hinged door mounted in the nacelle skin and actuated by a screw jack located in the support strut.

The cowl entrance area was purposely made larger than that required for the engine air flow in order to permit investigation of the full range of flexibility afforded by the combination of translating spike and variable-area bypass.

Engine rotative speed was sensed by a pulse-generator-type tachometer pickup which was incorporated in the starter drive. Control of the engine rotative speed was by manual operation of the fuel throttle.

The total- and static-pressure survey rakes at the compressor face were used to measure air flow and pressure recovery. Values presented as "indicated" total-pressure ratio were read from an instrument which indicated the ratio of the pressure from an averaging rake at the compressor face to a total pressure measured in the tunnel bellmouth. This averaging rake is standard equipment on the J34 and consists of several impact holes venting into one of the front compressor bearing support struts. During operation, this indicator was observed to yield values of total-pressure ratio within 1 percentage point of that computed from the total-pressure-survey values.

Four tubes were added to the inlet section of the model to sense pressures required for the shock-positioning controls. The conical spike was truncated slightly to allow a 1/16-inch-diameter impact tube to be placed such that it would sense total pressure behind a normal shock occurring at free-stream conditions. A cone surface static-pressure tap was placed approximately 3 inches behind the total-pressure tube (fig. 1(b)). An impact tube and a static tap were located on the cowl approximately on the horizontal center line, but separated

circumferentially by approximately 1 inch (fig. 1(c)). The two impact tubes were connected to a differential pressure switch. The two static taps were connected to a similar switch. The differential pressure switch (ref. 1) consisted of two low-volume (1 cc) chambers separated by a flexible rubber diaphragm (see fig. 1(d)). Two electrical contacts were located so that as the differential pressure between the two chambers was varied, a circuit was first closed on one side, then open on both sides, and finally closed on the remaining side. The pressure switch connected to the impact pressures was tested as a control for the reversible drive motor which positioned the adjustable spike. The 3498
pressure switch connected to the static taps was tested as a control for the spike drive or the bypass actuator.

Variables imposed upon the control system were engine rpm and free-stream Mach number. Tests of the terminal-shock-position controls were made at constant free-stream Mach number with variable engine rpm. Variable Mach number tests of the combined control were made with essentially constant engine speed while the free-stream Mach number was varied by means of the tunnel flexible wall.

RESULTS AND DISCUSSION

Typical performance curves for the inlet of this investigation are presented in figures 2 and 3 for a free-stream Mach number M_0 of 1.9. These curves illustrate that the inlet can deliver a given engine air flow with a variety of combinations of spike position and bypass opening which will have a corresponding variety of pressure recoveries. Operation of this diffuser with variable air flow, nearly maximum pressure recovery, and drag considerably less than encountered with subcritical spillage can be obtained by maintaining the diffuser terminal shock at a position near the cowl entrance through variation of the spike position. An alternative mode of operation which provides a further reduction of drag (ref. 4) with a pressure recovery somewhat less than the maximum is to position the terminal shock near the cowl entrance by means of the variable-area bypass.

Terminal-Shock-Positioning Control Systems

The schematic operation of a control for two conditions of terminal-shock position is illustrated in figure 4. The condition shown in figure 4(a) is one in which the equivalent air flow required at the exit of the diffuser is greater than the equivalent air flow that can enter the diffuser at critical inlet conditions, and therefore the terminal shock has moved into the diffuser. The sensing pressure p_l is essentially equal to the reference pressure p_c, and the switch contacts

are arranged to be closed on one side. The electric circuit is set to operate the bypass actuator in the closing direction or to move the spike in the retracting direction. If either of these actions is taken, the condition shown in figure 4(b) will result - the terminal shock will move forward of the sensing station, and the sensing pressure will be higher than the reference pressure p_c. The circuit is changed to the opposite set of contacts when this change occurs, and the actuator being controlled operates in the reverse direction relative to the initial
3498 case.

Terminal shock positioned by spike translation. - The static-pressure differential available to operate the pressure switch as the engine air flow is varied is shown in figure 5 for two fixed spike positions. These data were obtained by manual operation of the engine with no inlet controls in effect. Since the particular switch used in these investigations was set to have an intermediate position in which neither of the contacts is closed, the control has a dead band, as shown in figure 5. The dead band, in which no control signal is received by the actuator, is insignificant in terms of variation of air flow, but helps relieve some of the reversing load on the actuator motor. The performance curves from figure 2 are included in figure 5 to illustrate more clearly the position of the dead band with respect to conventional inlet performance parameters.

In practice, the pressure required to operate the differential switch is an absolute value, and the width and position of the dead band will therefore vary with altitude. In this installation the combination of dead-band pressure and location of the sensing pressure station inside the lip was chosen to give a control point slightly supercritical at the tunnel pressure altitude of approximately 34,500 feet.

The operation of the terminal-shock-position control connected to operate the spike-position actuator is presented in figure 6 for a range of 76 to 100 percent rated engine rpm and M_0 of 1.9. The mass-flow ratio indicated for the control data was obtained from reference 5 for the cowl position parameters indicated. As the engine speed was increased above 88 percent of rated (fig. 6), the control set the oblique shock farther inside the cowl lip, and therefore an increasing portion of the air received only normal shock compression. For these conditions there was no advantage with respect to pressure recovery or drag over supercritical operation with oblique shock on the lip. The control did function properly, however, positioning the terminal shock at the cowl lip station. As the oblique shock was moved ahead of the cowl lip to provide supersonic mass-flow spillage (speeds below 88 percent of rated), the pressure recovery remained essentially constant. The solid symbols are data from figure 2 for critical flow conditions at comparable spike positions. These symbols indicate that, as predicted from the pressure coefficient data, the control set the diffuser at approximately the critical operating condition.

Terminal shock positioned by variable bypass. - With the use of the same static-pressure sensing system illustrated in figure 4, the position of the terminal shock can also be controlled by varying the discharge area of the bypass. The static-pressure differential available to operate the pressure switch as the engine air flow is varied is shown in figure 7 for two different bypass positions, fully open and fully closed. Data for the pressure coefficients were obtained by manually operating the engine with no inlet controls. Also reproduced in figure 7 are the faired inlet performance data from figure 3. As indicated by the dead band of the pressure switch, the control point was slightly supercritical, as before. Operation of this control over a range of engine revolutions from 91 to 100 percent rated is shown in figure 8. The hunting zone indicated for this control combination occurred at a frequency of the order of 1 to 1/2 cycle per second and is believed to have been caused by coasting of the actuator through the dead band rather than by any inherent instability. At 99 percent rated engine speed, the indicated hunting band amounted to approximately 3 percent of the engine air flow. This control maintained a constant pressure recovery over the range of engine speed variations tested corresponding to almost the full range of bypass travel. Comparison of this pressure recovery with the data for a comparable spike position from reference 3 indicates that the control maintained the flow at near critical conditions. Within the range investigated, neither of the terminal-shock-position controls allowed the diffuser to enter the unstable zone.

Combination Control

The combination of translating spike and variable-area bypass permits a diffuser to be operated at minimum drag as flight Mach number is varied by translating the spike to keep the conical shock near the cowl lip. Figure 9 shows schematically the system used to maintain the conical-shock position. The impact tube in the cone tip (reading P_c) and the impact tube just inside the cowl lip (reading P_l) are connected to opposite sides of a differential pressure switch. In figure 9(a) the oblique shock is inside the cowl lip, and the impact tube inside the cowl lip reads approximately the total-pressure recovery behind a normal shock occurring at free-stream conditions. Therefore, this shock-sensing pressure P_l will approximately equal the reference impact pressure P_c located at the cone tip. Under these conditions, the pressure capsule was set to signal an extension of the spike. As the spike was extended, the vortex sheet formed by the intersection of the bow wave in front of the cowl lip and the oblique shock crossed the total-pressure tube which measured P_l. When the vortex sheet was outside the shock-sensing impact tube (fig. 9(b)), the pressure at this tube was that behind one oblique and one normal shock, and therefore was higher than that sensed by the reference tube in the cone tip. This pressure differential closed the opposite contacts in the pressure switch and thereby retracted the spike. The bow wave shown in the illustrations is the condition induced by bluntness of the cowl lip; however, this does not affect the principal of operation.

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With the conical shock on the cowl, the inlet will generally supply more air at critical flow conditions than that required by an engine operating at a constant rotative speed over a range of Mach number. Subcritical operation was avoided by using the bypass to spill the excess air while maintaining the terminal shock near the cowl entrance. The hunting illustrated in figure 8 was prevented by connecting the output of the normal-shock-positioning differential pressure switch to a signal light in the control panel rather than directly to the bypass motor. The bypass was then manually positioned by the signals from these lights.

So that this combined system could be investigated over a range of free-stream Mach numbers, the tunnel Mach number was varied continuously from 1.7 to 2.0 with the flexible wall. The performance of the combined control is shown in figure 10. In the Mach number range from 1.75 to 2.0, comparison of the cowl position data for inlet control in operation with the value of cowl parameter necessary for oblique shock - cowl lip intersection (dotted curve, fig. 10) indicated that the oblique shock was always positioned slightly ahead of the cowl lip. As the Mach number was decreased, the bow wave moved farther ahead of the lip and thus the control position became farther forward of the cowl lip. This condition could be remedied by repositioning the cowl lip impact tube. Figure 10 also shows that for Mach numbers below 1.75, the bypass was fully open. With further reduction of the Mach number, the normal shock moved out of the diffuser, but the spike continued to translate and maintained the vortex sheet at the control position.

For control spike positions with the oblique shock near the cowl lip, the pressure recovery was very nearly equal to the critical recovery (ref. 3) for oblique shock on the lip. As the control shock setting moved ahead of the cowl lip, the pressure recovery exceeded that for intersection of the oblique shock with the cowl lip. This would be expected from consideration of the data in figure 2.

The operation of the automatic diffuser controls with a manually controlled turbojet engine did not reveal any serious interactions between the inlet and the engine. It remains to be shown that an engine installation with completely automatic inlet and engine controls will not suffer interactions between the control systems themselves.

SUMMARY OF RESULTS

The following results were obtained from an investigation of shock-positioning controls for a variable-geometry inlet in combination with a J34 turbojet engine:

1. With a combination control system in which the bypass opening was controlled by the terminal-shock position and the spike translation was controlled by the conical-shock position, the diffuser was automatically maintained at near-critical conditions over the range of Mach numbers from 1.75 to 2.0. For Mach numbers below 1.75, the bypass capacity was too small to maintain the terminal shock at critical position. As a result of this, the translating spike control acted to position the vortex sheet from the conical shock - normal shock intersection.

2. At a free-stream Mach number of 1.9, the terminal shock was automatically maintained near critical by means of either the bypass or the translating spike as engine rpm was varied. The full bypass travel allowed the engine rpm to be varied from 91 to 100 percent of rated, and the translating spike maintained control for a 76 to 100 percent variation in engine rpm.

3. As far as automatic control of this particular combination of variable-geometry diffuser and manually operated J34 engine is concerned, there were no observable interactions between the diffuser and the engine.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, September 29, 1954

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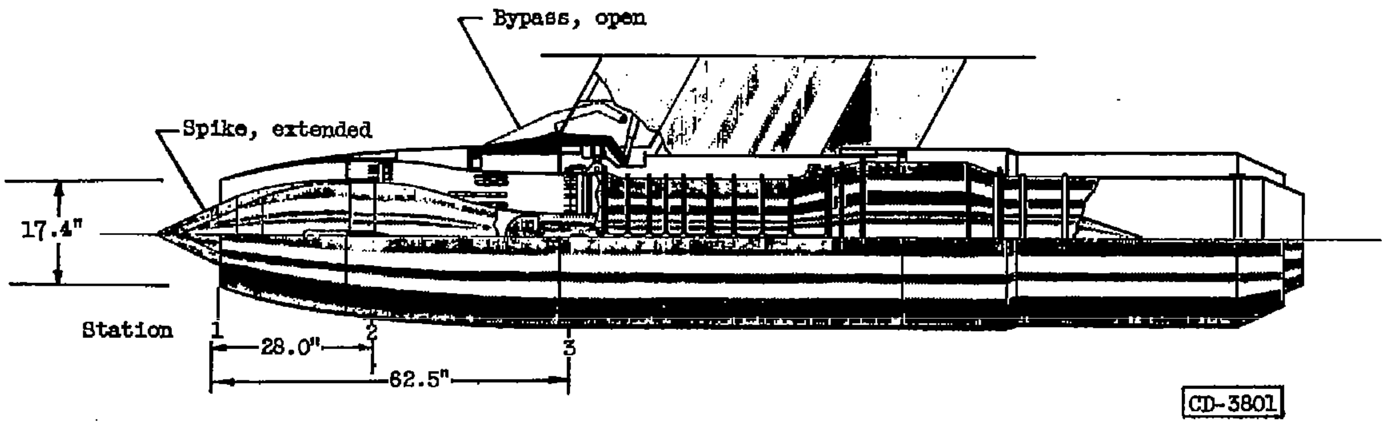
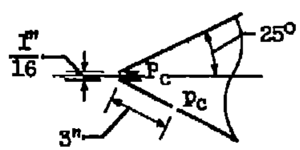
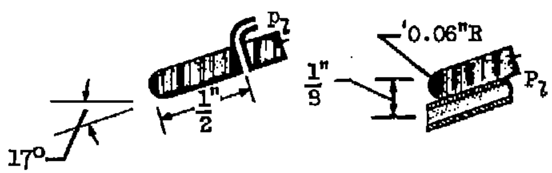


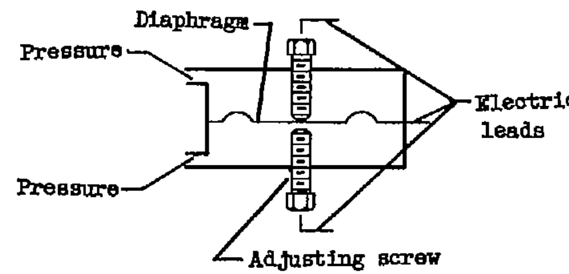
(a) Nacelle installation of J34 turbojet engine.



(b) Cone tip detail.



(c) Cowl lip details.



(d) Schematic of differential pressure switch.

Figure 1. - Configuration details.

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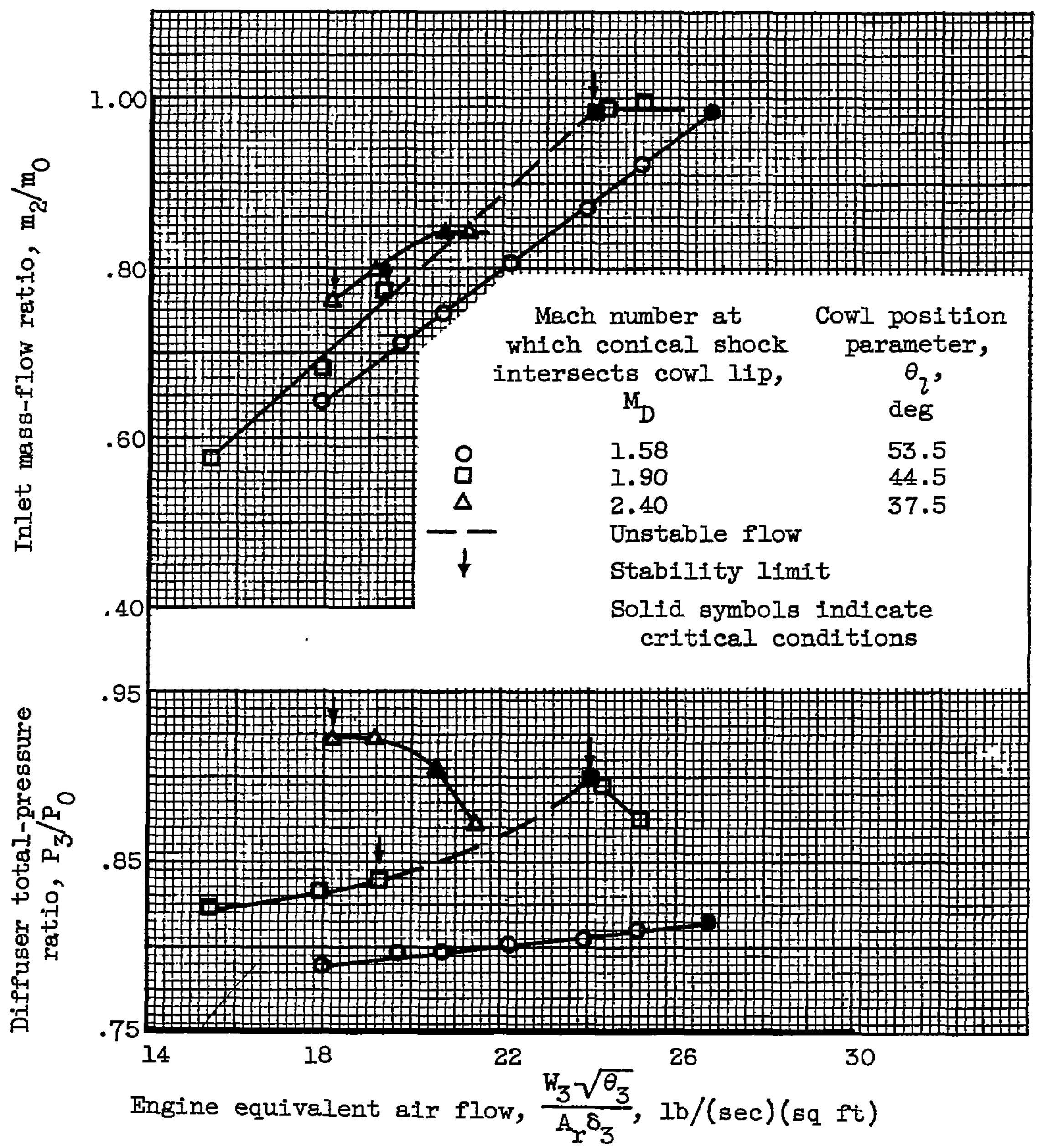

Figure 2. - Effect of spike translation on diffuser performance characteristics at Mach 1.9. Automatic control disconnected.

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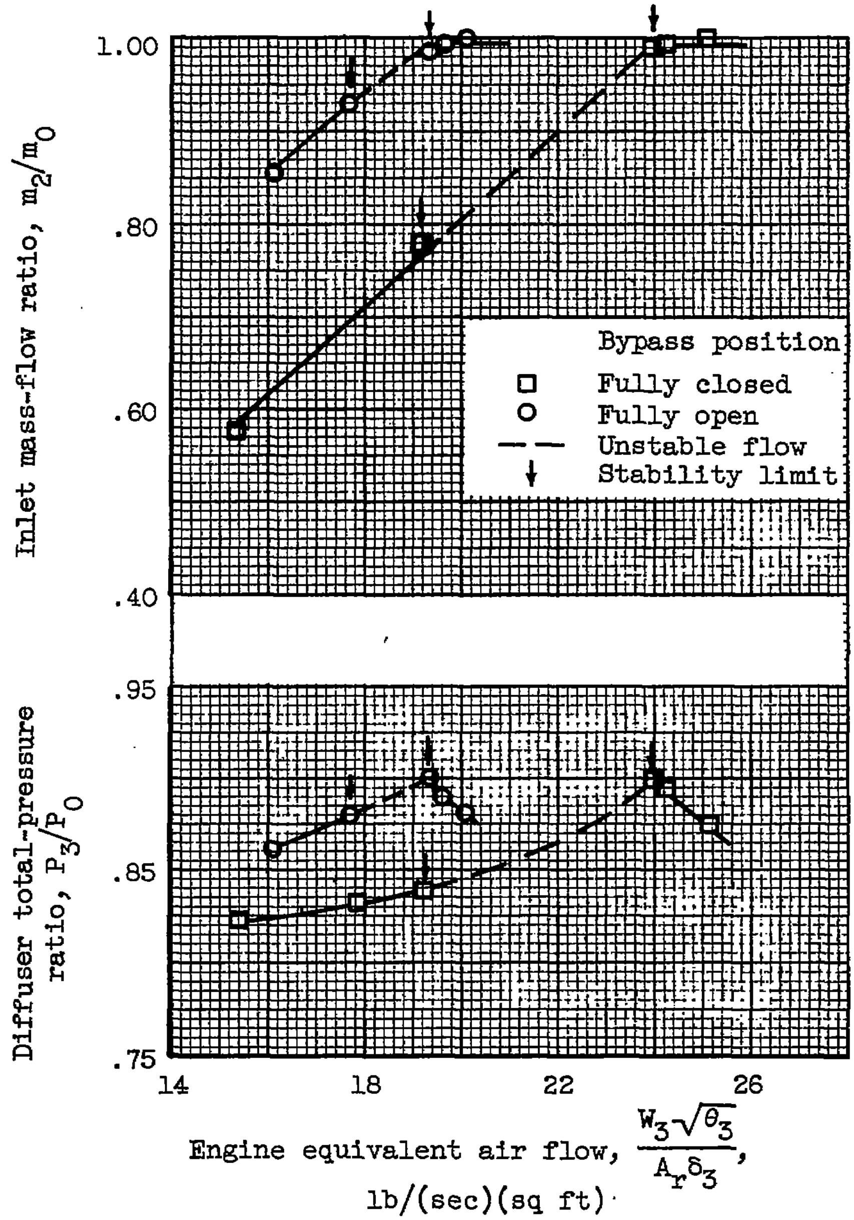

Figure 3. - Effect of bypass position on diffuser performance characteristics at Mach 1.9. Mach number at which conical shock intersects cowl lip, M_D, 1.90 (conical shock on lip). Automatic control disconnected.

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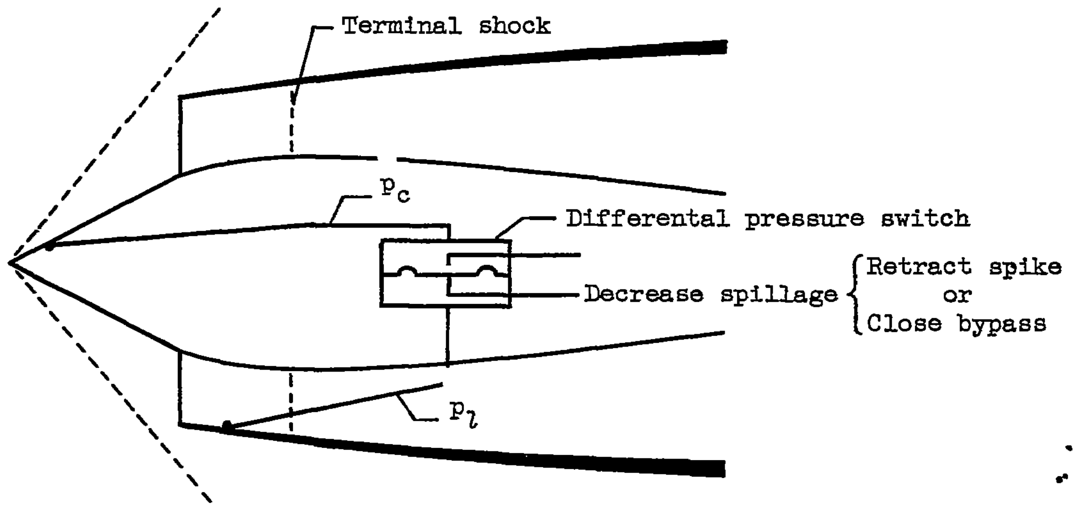
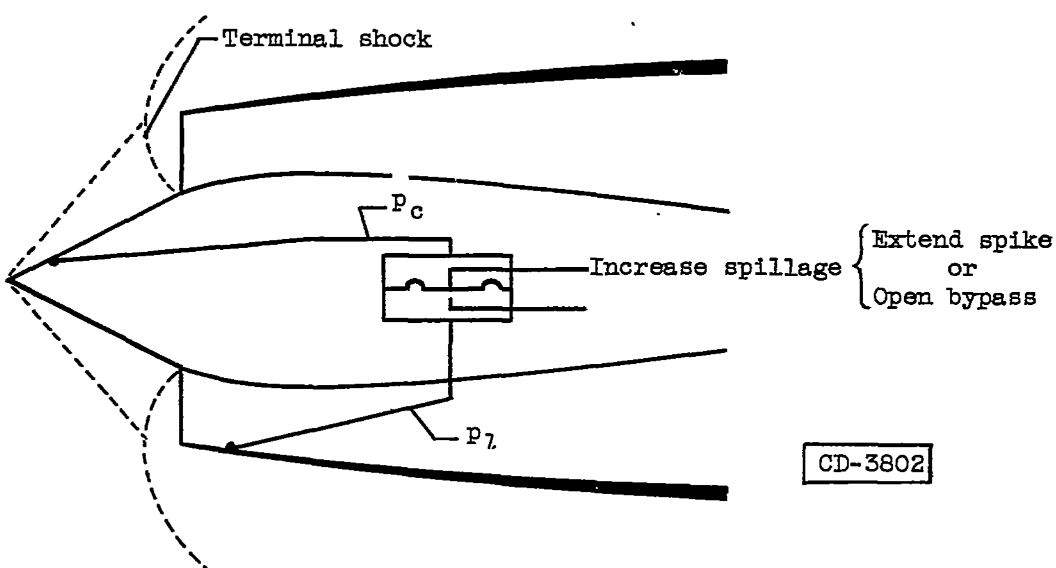


(a) Supercritical operation; $p_c \approx p_l$.



(b) Subcritical operation, $p_c < p_l$.

Figure 4. - Illustration of control designed to position terminal shock.

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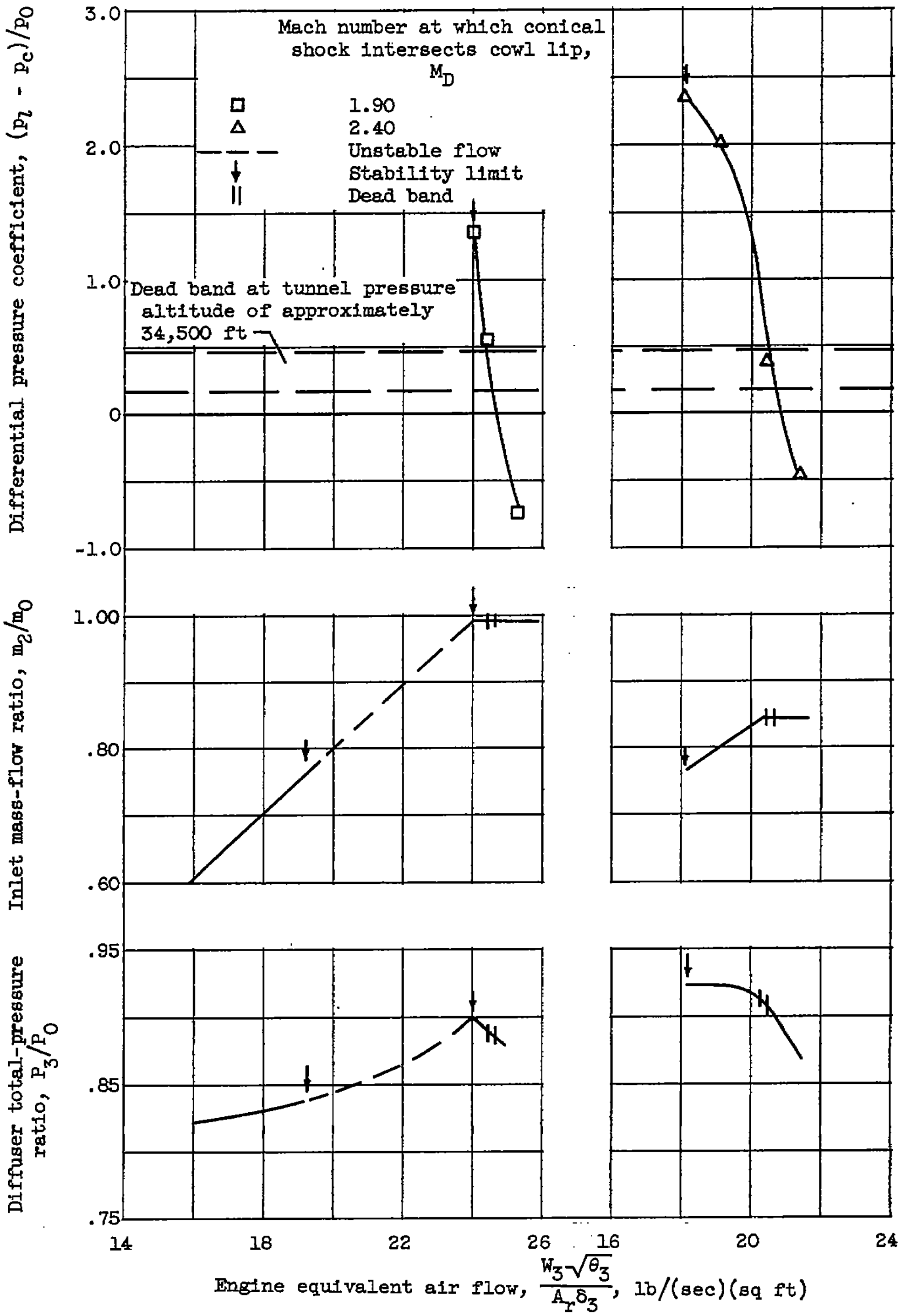

Figure 5. - Effect of spike position on control pressures at Mach 1.9. Faired curves of figure 2 are included for comparison. Automatic control disconnected.

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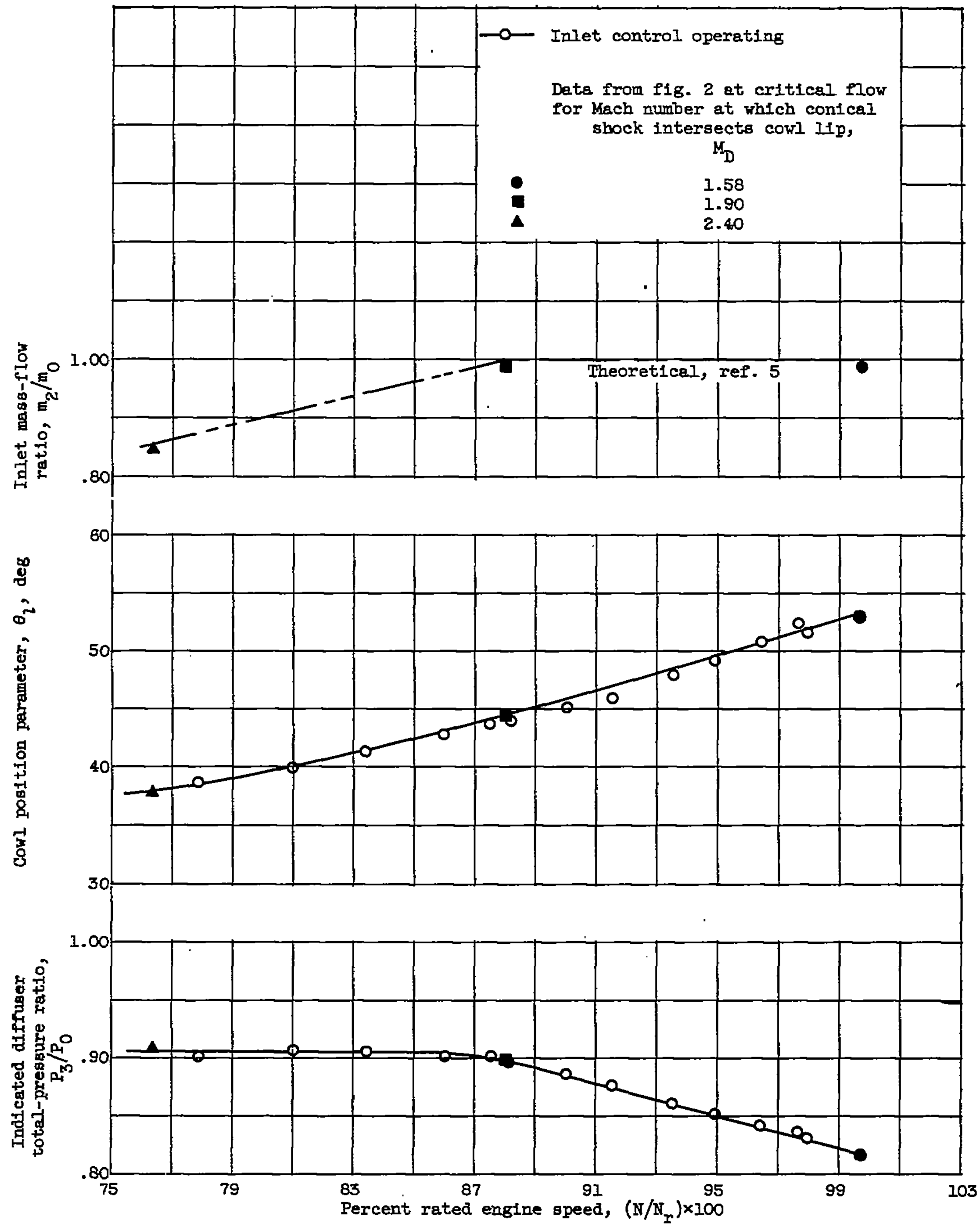

Figure 6. - Critical control by automatic spike translation. Mach 1.9; bypass fully open.

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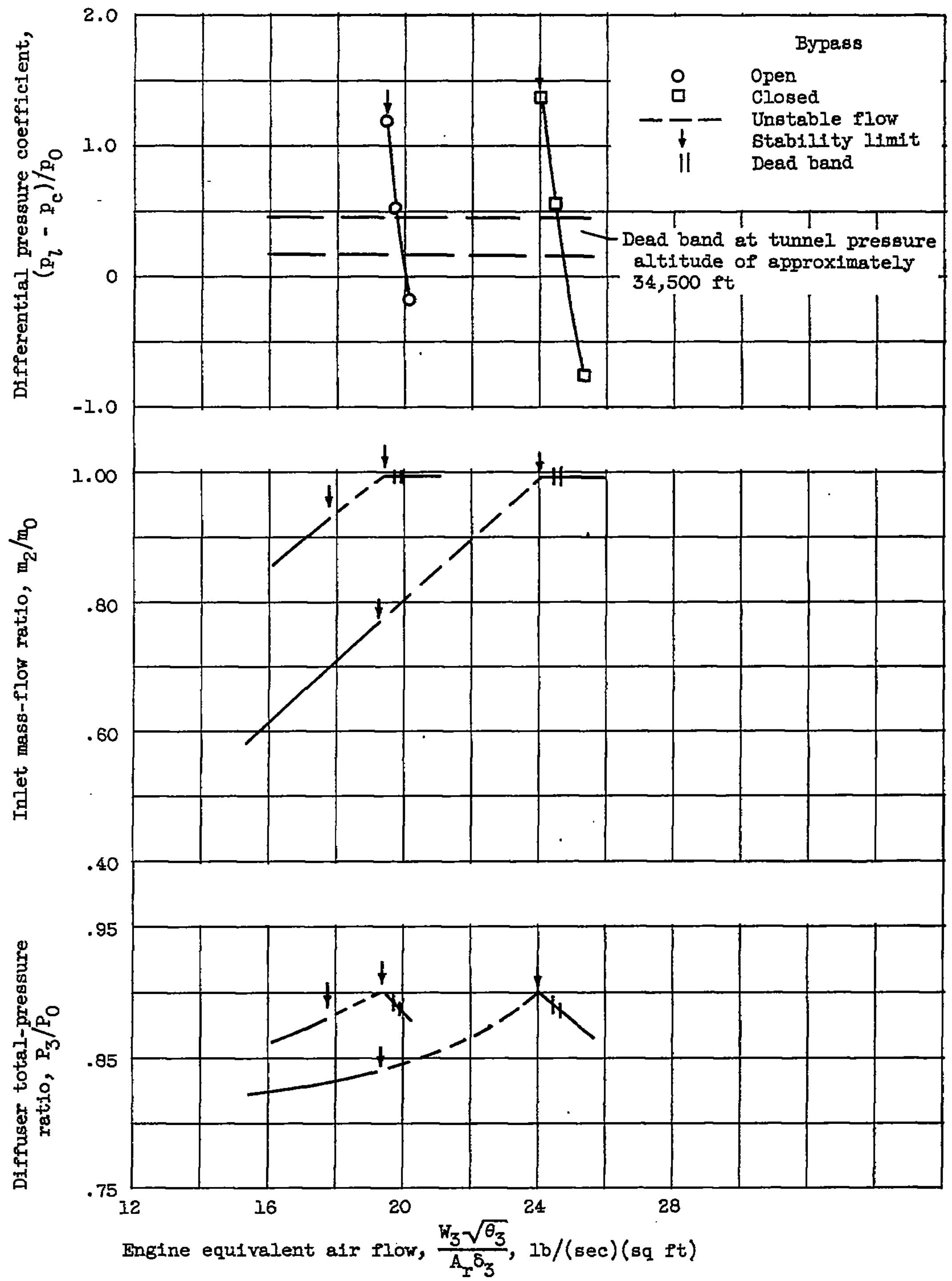

Figure 7. - Effect of bypass position on control pressures at Mach 1.9. Faired curves of figure 3 included for comparison. Mach number at which conical shock intersects cowl lip M_D equal to free-stream Mach number M_0. Automatic control disconnected.

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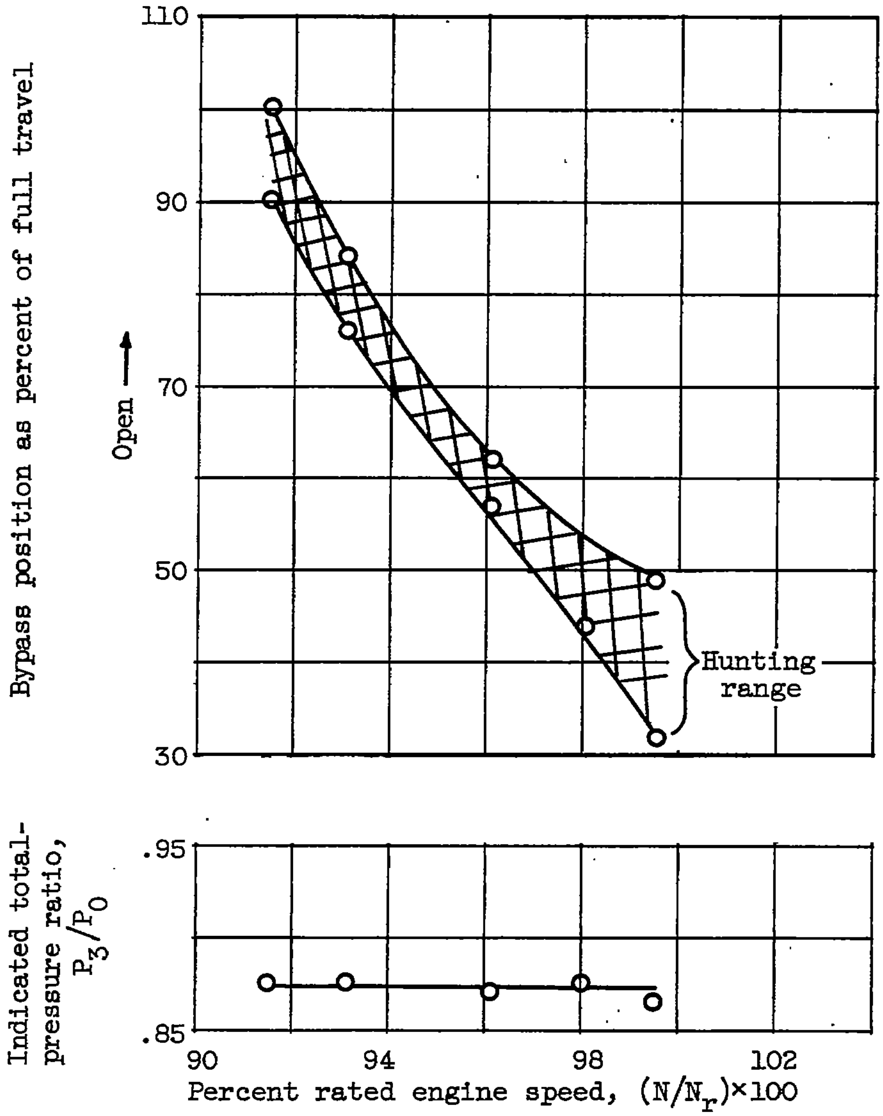
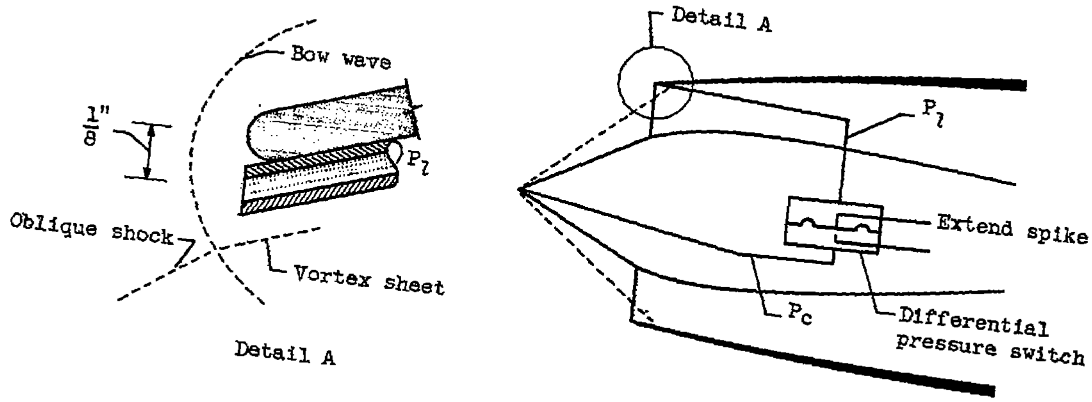
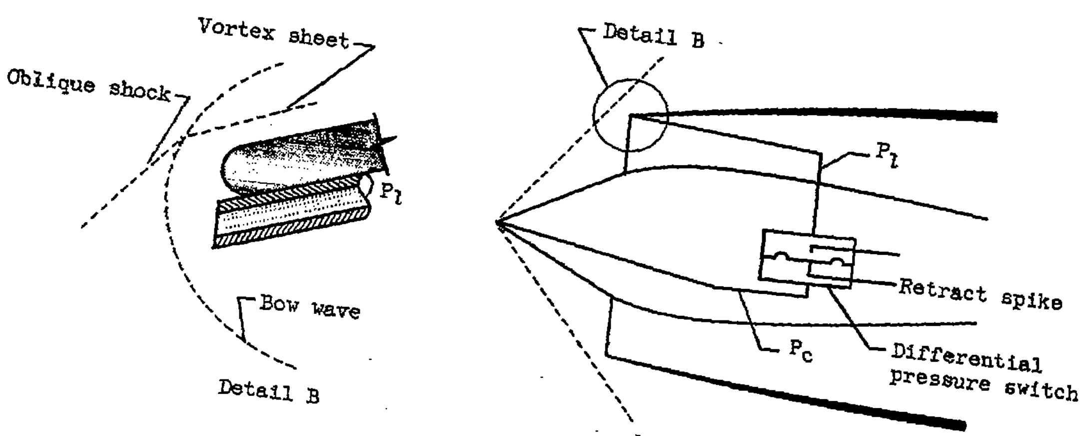


Figure 8. - Bypass automatically controlled by terminal-shock position. Operation at Mach 1.9; cowl position parameter, θ_l, 45.8°.



(a) Vortex sheet inside cowl; $P_c \approx P_l$.



(b) Vortex sheet outside cowl; $P_c < P_l$.

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Figure 9. - Illustration of control designed to position oblique shock.

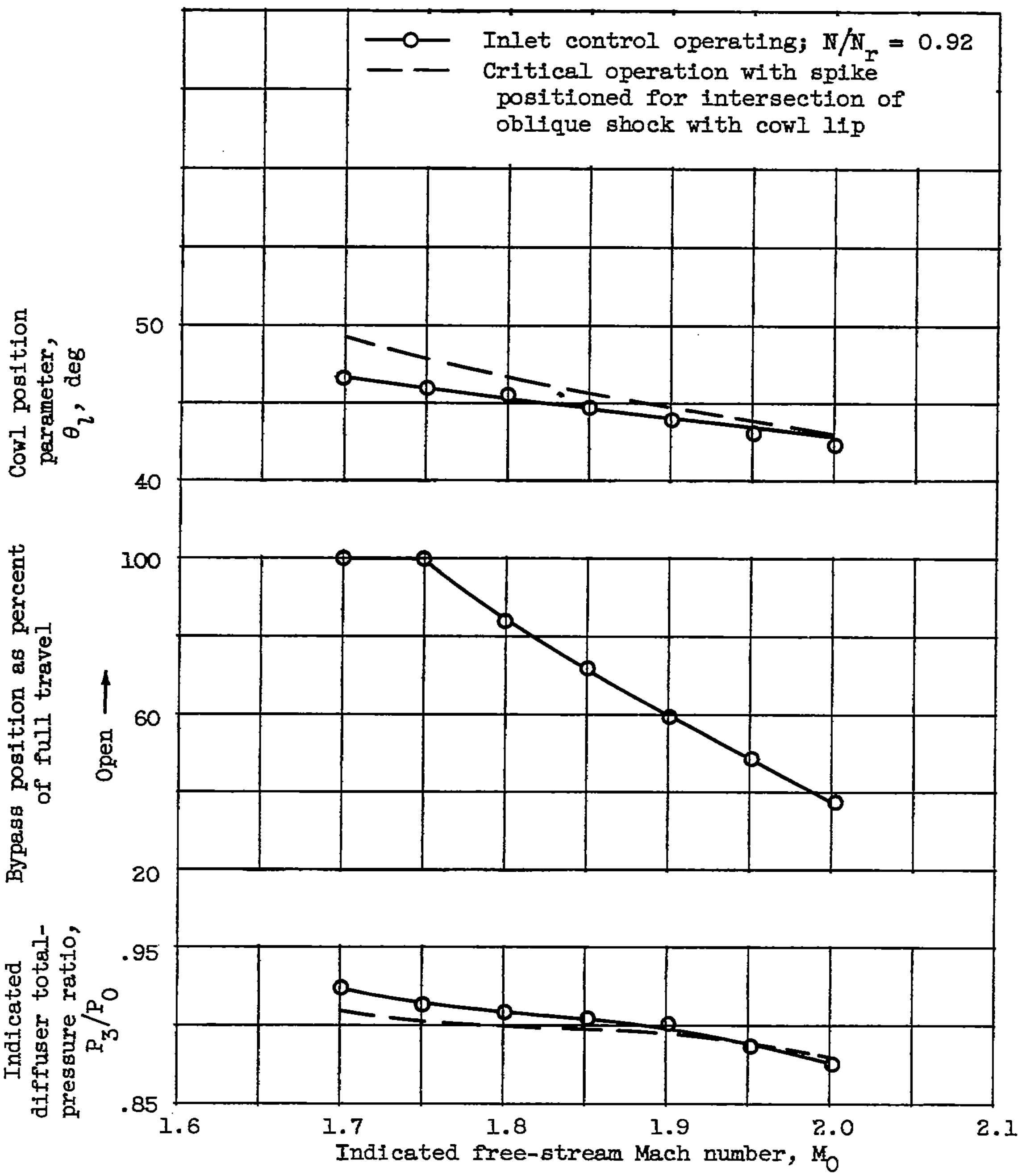

Figure 10. - Performance of combined control.

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SUMMARY

Shock-positioning controls designed to actuate the translating spike and the variable bypass of a variable-geometry inlet were investigated in the 8- by 6-foot supersonic tunnel. The operation of this inlet was observed in combination with a J34 turbojet engine at tunnel Mach numbers from 1.7 to 2.0. At Mach number 1.9, it was demonstrated that either the translating spike or the bypass could be automatically actuated to maintain the inlet terminal shock just inside the cowl lip over a range of engine mass flow. With the bypass controlled by the terminal shock and the spike translation controlled by the conical shock, the inlet was automatically maintained near critical air flow as the Mach number was varied from 2.0 to 1.75 with constant engine rotative speed.

INTRODUCTION

The control of fuel flow by inlet-shock position has been successfully applied to a ram jet (refs. 1 and 2). One control system illustrated that the relation between conical shock position and flight Mach number can be employed to maintain a preselected flight speed. Another control system for this ram jet utilized the interrelation of the terminal shock position and the diffuser performance to maintain the inlet near critical conditions. The results obtained with the ram jet were used to devise similar systems for the inlet of the turbojet engine of reference 3. One control system which was investigated at a free-stream Mach number M_0 of 1.9 was arranged so that the position of the terminal shock would automatically control the spilling of air by either the bypass or the translation of the spike. A second control system was used in conjunction with the translating spike to maintain the conical shock near the cowl lip as the stream Mach number was varied from 1.7 to 2.0.

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M Mach number

M_D Mach number at which conical shock intersects cowl lip

m mass flow

N engine rotational speed, rpm

N_r rated engine rotational speed, 12,500 rpm

P total pressure, abs

p static pressure, abs

W_3 air flow rate measured at compressor face, lb/sec

δ total pressure divided by NACA standard sea-level absolute pressure

θ total temperature divided by NACA standard sea-level absolute temperature

θ_l angle between axis of cone and line joining cone tip and cowl lip, deg

Subscripts:

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RESULTS AND DISCUSSION

Typical performance curves for the inlet of this investigation are presented in figures 2 and 3 for a free-stream Mach number M_0 of 1.9. These curves illustrate that the inlet can deliver a given engine air flow with a variety of combinations of spike position and bypass opening which will have a corresponding variety of pressure recoveries. Operation of this diffuser with variable air flow, nearly maximum pressure recovery, and drag considerably less than encountered with subcritical spillage can be obtained by maintaining the diffuser terminal shock at a position near the cowl entrance through variation of the spike position. An alternative mode of operation which provides a further reduction of drag (ref. 4) with a pressure recovery somewhat less than the maximum is to position the terminal shock near the cowl entrance by means of the variable-area bypass.

Terminal-Shock-Positioning Control Systems

The schematic operation of a control for two conditions of terminal-shock position is illustrated in figure 4. The condition shown in figure 4(a) is one in which the equivalent air flow required at the exit of the diffuser is greater than the equivalent air flow that can enter the diffuser at critical inlet conditions, and therefore the terminal shock has moved into the diffuser. The sensing pressure p_l is essentially equal to the reference pressure p_c, and the switch contacts are arranged to be closed on one side. The electric circuit is set to operate the bypass actuator in the closing direction or to move the spike in the retracting direction. If either of these actions is taken, the condition shown in figure 4(b) will result - the terminal shock will move forward of the sensing station, and the sensing pressure will be higher than the reference pressure p_c. The circuit is changed to the opposite set of contacts when this change occurs, and the actuator being controlled operates in the reverse direction relative to the initial case.

<u>Terminal shock positioned by spike translation</u>. - The static-pressure differential available to operate the pressure switch as the engine air flow is varied is shown in figure 5 for two fixed spike positions. These data were obtained by manual operation of the engine with no inlet controls in effect. Since the particular switch used in these investigations was set to have an intermediate position in which neither of the contacts is closed, the control has a dead band, as shown in figure 5. The dead band, in which no control signal is received by the actuator, is insignificant in terms of variation of air flow, but helps relieve some of the reversing load on the actuator motor. The performance curves from figure 2 are included in figure 5 to illustrate more clearly the position of the dead band with respect to conventional inlet performance parameters.

In practice, the pressure required to operate the differential switch is an absolute value, and the width and position of the dead band will therefore vary with altitude. In this installation the combination of dead-band pressure and location of the sensing pressure station inside the lip was chosen to give a control point slightly supercritical at the tunnel pressure altitude of approximately 34,500 feet.

The operation of the terminal-shock-position control connected to operate the spike-position actuator is presented in figure 6 for a range of 76 to 100 percent rated engine rpm and M_0 of 1.9. The mass-flow ratio indicated for the control data was obtained from reference 5 for the cowl position parameters indicated. As the engine speed was increased above 88 percent of rated (fig. 6), the control set the oblique shock farther inside the cowl lip, and therefore an increasing portion of the air received only normal shock compression. For these conditions there was no advantage with respect to pressure recovery or drag over supercritical operation with oblique shock on the lip. The control did function properly, however, positioning the terminal shock at the cowl lip station. As the oblique shock was moved ahead of the cowl lip to provide supersonic mass-flow spillage (speeds below 88 percent of rated), the pressure recovery remained essentially constant. The solid symbols are data from figure 2 for critical flow conditions at comparable spike positions. These symbols indicate that, as predicted from the pressure coefficient data, the control set the diffuser at approximately the critical operating condition.

Terminal shock positioned by variable bypass. - With the use of the same static-pressure sensing system illustrated in figure 4, the position of the terminal shock can also be controlled by varying the discharge area of the bypass. The static-pressure differential available to operate the pressure switch as the engine air flow is varied is shown 3498
in figure 7 for two different bypass positions, fully open and fully closed. Data for the pressure coefficients were obtained by manually operating the engine with no inlet controls. Also reproduced in figure 7 are the faired inlet performance data from figure 3. As indicated by the dead band of the pressure switch, the control point was slightly supercritical, as before. Operation of this control over a range of engine revolutions from 91 to 100 percent rated is shown in figure 8. The hunting zone indicated for this control combination occurred at a frequency of the order of 1 to 1/2 cycle per second and is believed to have been caused by coasting of the actuator through the dead band rather than by any inherent instability. At 99 percent rated engine speed, the indicated hunting band amounted to approximately 3 percent of the engine air flow. This control maintained a constant pressure recovery over the range of engine speed variations tested corresponding to almost the full range of bypass travel. Comparison of this pressure recovery with the data for a comparable spike position from reference 3 indicates that the control maintained the flow at near critical conditions. Within the range investigated, neither of the terminal-shock-position controls allowed the diffuser to enter the unstable zone.

Combination Control

The combination of translating spike and variable-area bypass permits a diffuser to be operated at minimum drag as flight Mach number is varied by translating the spike to keep the conical shock near the cowl lip. Figure 9 shows schematically the system used to maintain the conical-shock position. The impact tube in the cone tip (reading P_c) and the impact tube just inside the cowl lip (reading P_l) are connected to opposite sides of a differential pressure switch. In figure 9(a) the oblique shock is inside the cowl lip, and the impact tube inside the cowl lip reads approximately the total-pressure recovery behind a normal shock occurring at free-stream conditions. Therefore, this shock-sensing pressure P_l will approximately equal the reference impact pressure P_c located at the cone tip. Under these conditions, the pressure capsule was set to signal an extension of the spike. As the

spike was extended, the vortex sheet formed by the intersection of the bow wave in front of the cowl lip and the oblique shock crossed the total-pressure tube which measured P_l. When the vortex sheet was outside the shock-sensing impact tube (fig. 9(b)), the pressure at this tube was that behind one oblique and one normal shock, and therefore was higher than that sensed by the reference tube in the cone tip. This pressure differential closed the opposite contacts in the pressure switch and thereby retracted the spike. The bow wave shown in the il-
3498 lustrations is the condition induced by bluntness of the cowl lip; however, this does not affect the principal of operation.

With the conical shock on the cowl, the inlet will generally supply more air at critical flow conditions than that required by an engine operating at a constant rotative speed over a range of Mach number. Subcritical operation was avoided by using the bypass to spill the excess air while maintaining the terminal shock near the cowl entrance. The hunting illustrated in figure 8 was prevented by connecting the output of the normal-shock-positioning differential pressure switch to a signal light in the control panel rather than directly to the bypass motor. The bypass was then manually positioned by the signals from these lights.

So that this combined system could be investigated over a range of free-stream Mach numbers, the tunnel Mach number was varied continuously from 1.7 to 2.0 with the flexible wall. The performance of the combined control is shown in figure 10. In the Mach number range from 1.75 to 2.0, comparison of the cowl position data for inlet control in operation with the value of cowl parameter necessary for oblique shock - cowl lip intersection (dotted curve, fig. 10) indicated that the oblique shock was always positioned slightly ahead of the cowl lip. As the Mach number was decreased, the bow wave moved farther ahead of the lip and thus the control position became farther forward of the cowl lip. This condition could be remedied by repositioning the cowl lip impact tube. Figure 10 also shows that for Mach numbers below 1.75, the bypass was fully open. With further reduction of the Mach number, the normal shock moved out of the diffuser, but the spike continued to translate and maintained the vortex sheet at the control position.

For control spike positions with the oblique shock near the cowl lip, the pressure recovery was very nearly equal to the critical recovery (ref. 3) for oblique shock on the lip. As the control shock setting moved ahead of the cowl lip, the pressure recovery exceeded that for intersection of the oblique shock with the cowl lip. This would be expected from consideration of the data in figure 2.

The operation of the automatic diffuser controls with a manually controlled turbojet engine did not reveal any serious interactions between the inlet and the engine. It remains to be shown that an engine installation with completely automatic inlet and engine controls will not suffer interactions between the control systems themselves.

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SUMMARY OF RESULTS

The following results were obtained from an investigation of shock-positioning controls for a variable-geometry inlet in combination with a J34 turbojet engine:

1. With a combination control system in which the bypass opening was controlled by the terminal-shock position and the spike translation was controlled by the conical-shock position, the diffuser was automatically maintained at near-critical conditions over the range of Mach numbers from 1.75 to 2.0. For Mach numbers below 1.75, the bypass capacity was too small to maintain the terminal shock at critical position. As a result of this, the translating spike control acted to position the vortex sheet from the conical shock - normal shock intersection.

2. At a free-stream Mach number of 1.9, the terminal shock was automatically maintained near critical by means of either the bypass or the translating spike as engine rpm was varied. The full bypass travel allowed the engine rpm to be varied from 91 to 100 percent of rated, and the translating spike maintained control for a 76 to 100 percent variation in engine rpm.

3. As far as automatic control of this particular combination of variable-geometry diffuser and manually operated J34 engine is concerned, there were no observable interactions between the diffuser and the engine.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, September 29, 1954

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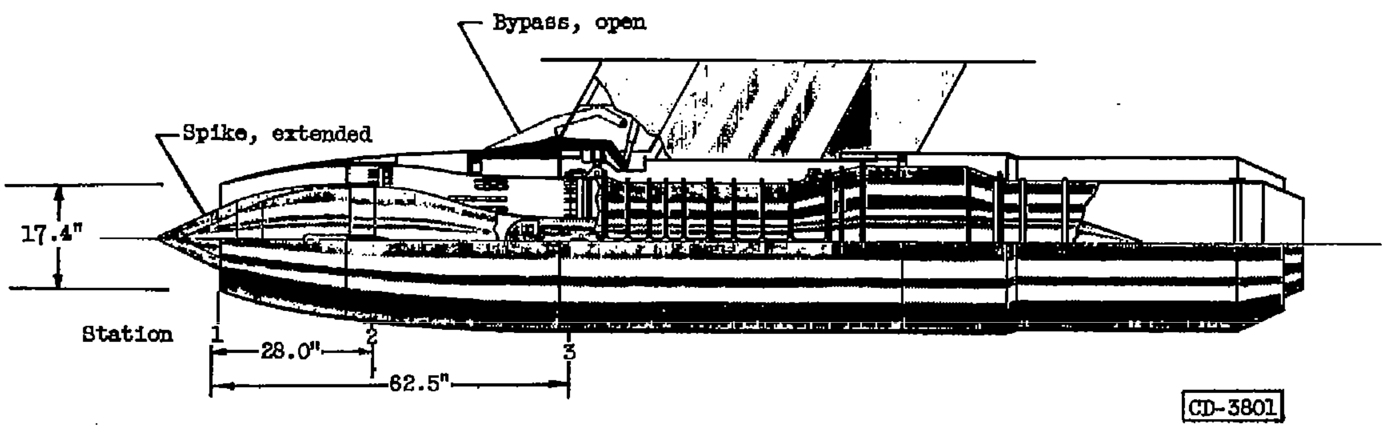
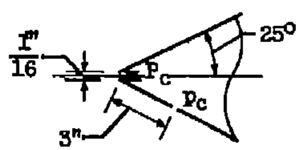
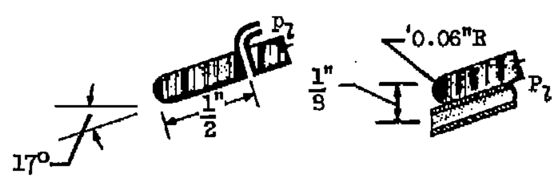


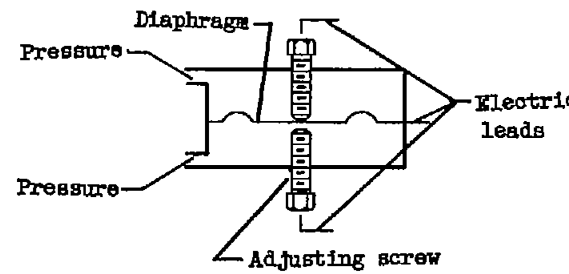
(a) Nacelle installation of J34 turbojet engine.



(b) Cone tip detail.



(c) Cowl lip details.



(d) Schematic of differential pressure switch.

Figure 1. - Configuration details.

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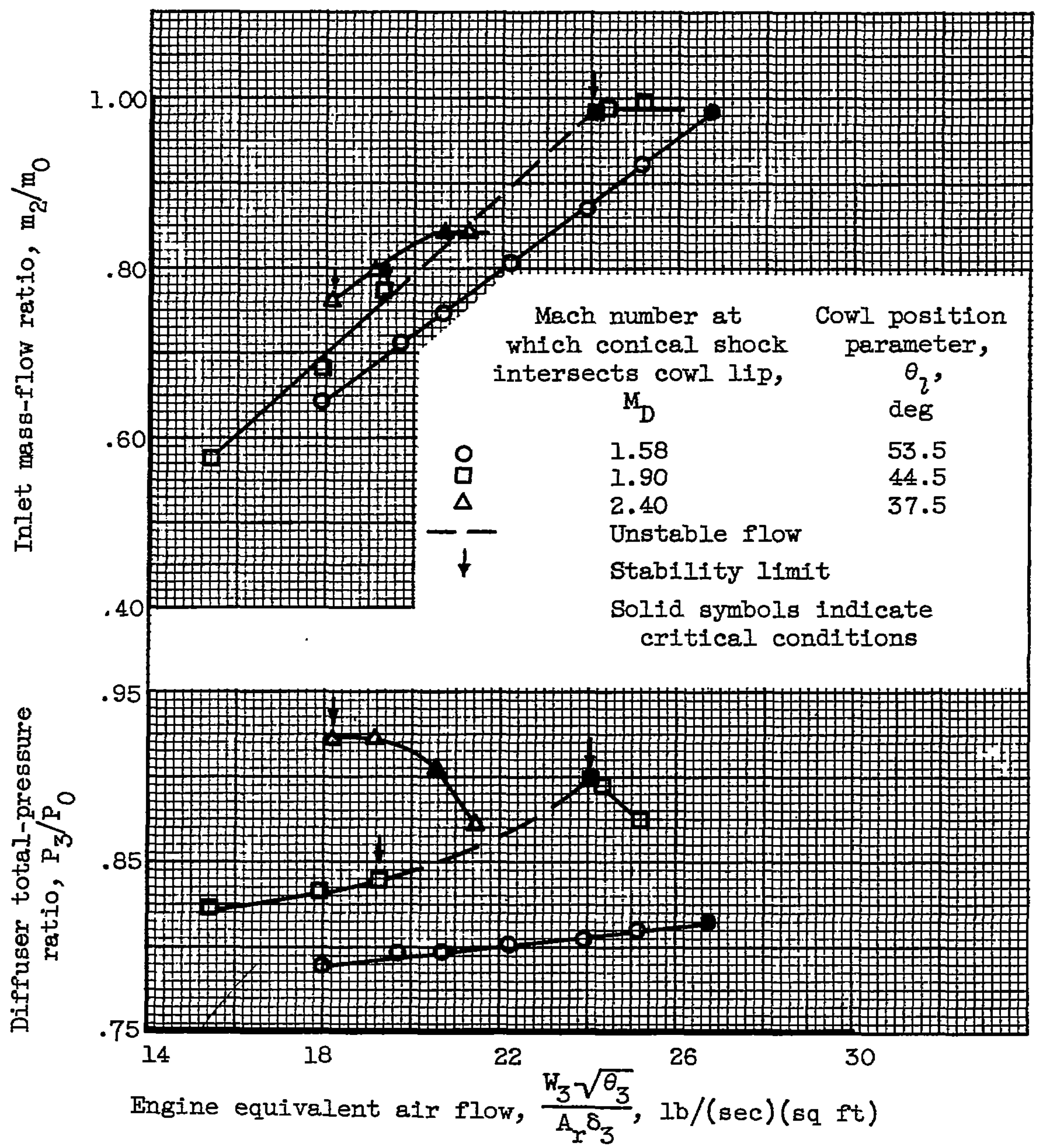

Figure 2. - Effect of spike translation on diffuser performance characteristics at Mach 1.9. Automatic control disconnected.

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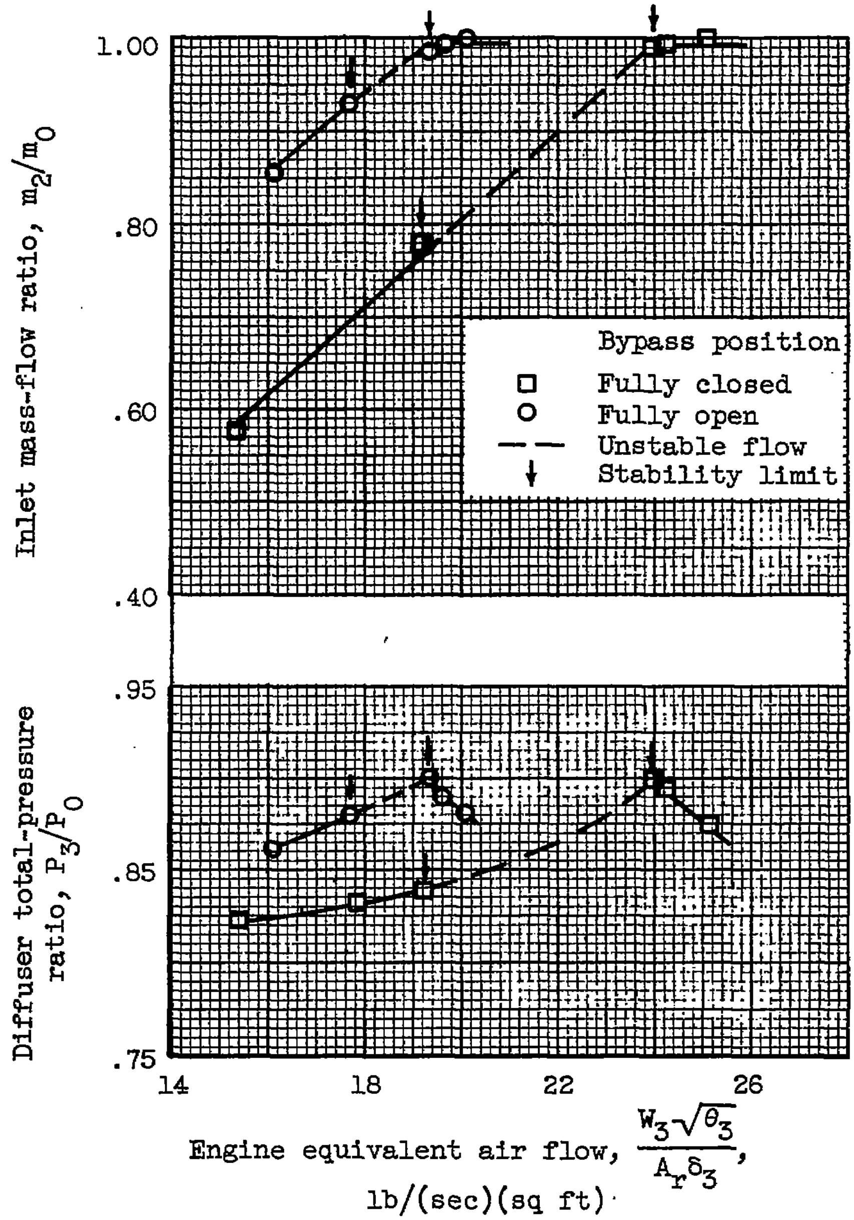

Figure 3. - Effect of bypass position on diffuser performance characteristics at Mach 1.9. Mach number at which conical shock intersects cowl lip, M_D, 1.90 (conical shock on lip). Automatic control disconnected.

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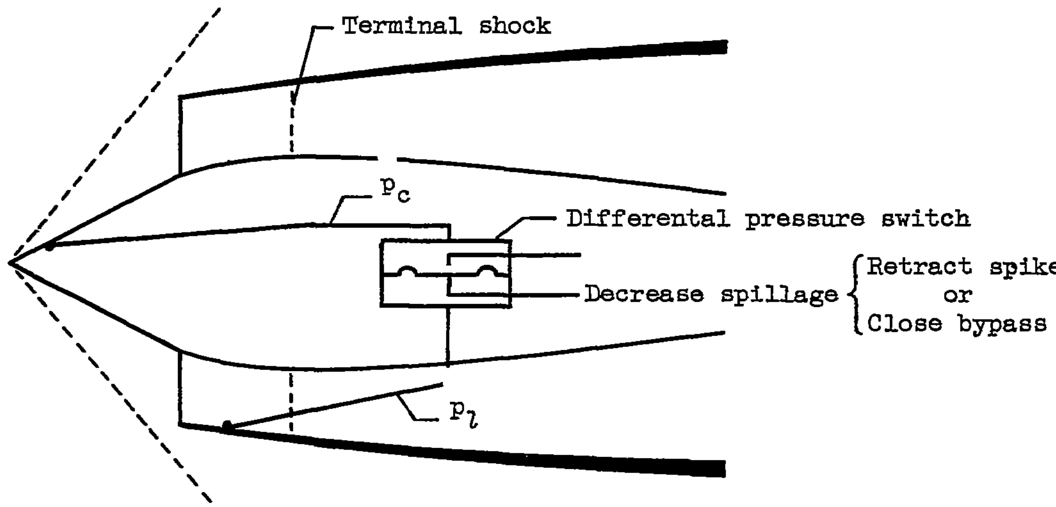
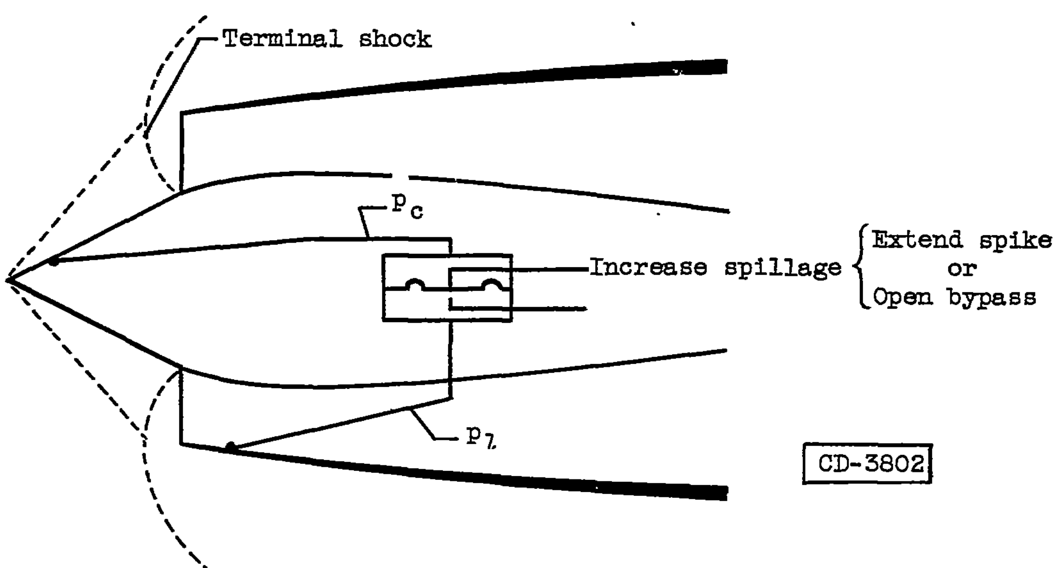


(a) Supercritical operation; $p_c \approx p_l$.



(b) Subcritical operation, $p_c < p_l$.

Figure 4. - Illustration of control designed to position terminal shock.

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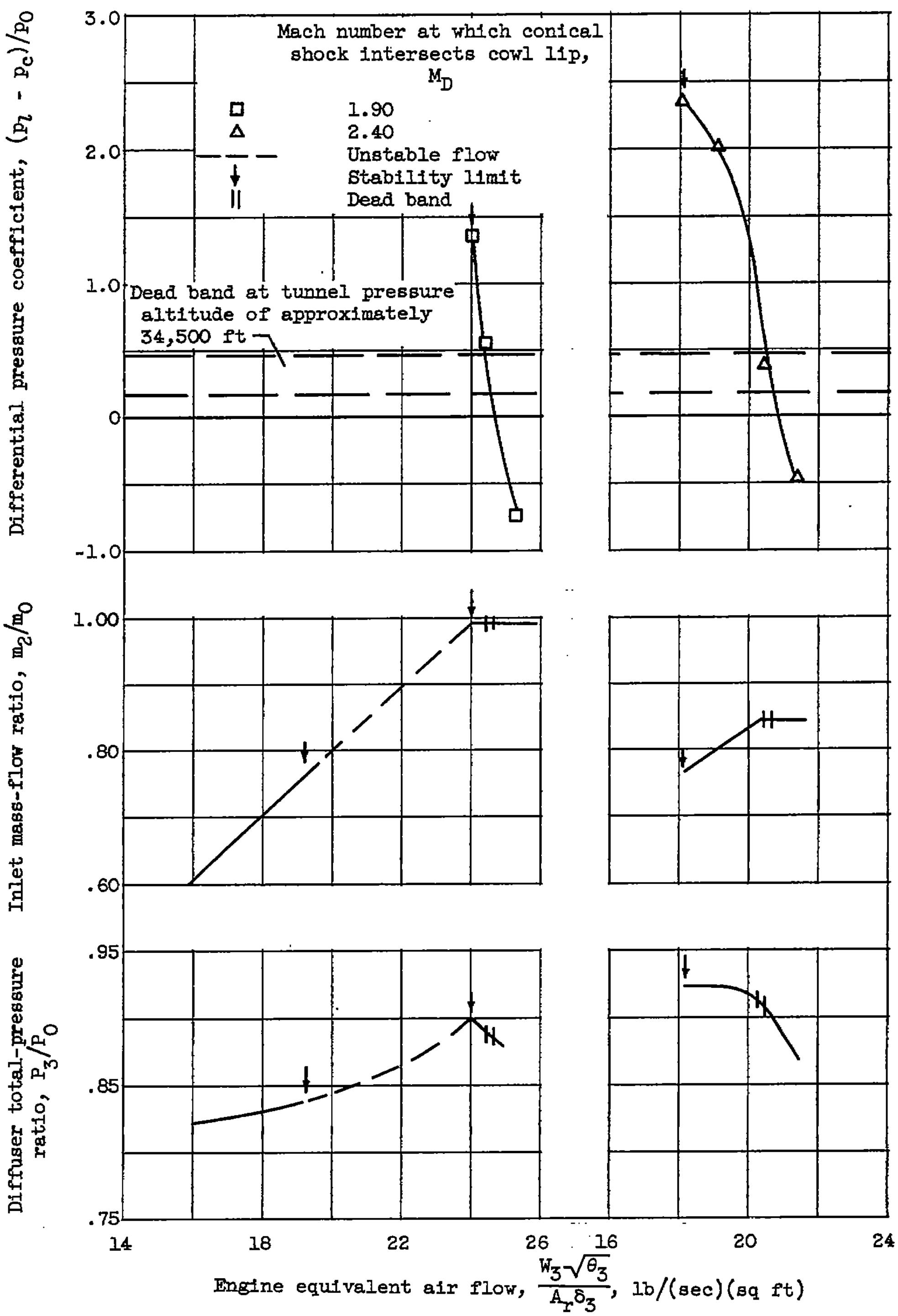

Figure 5. - Effect of spike position on control pressures at Mach 1.9. Faired curves of figure 2 are included for comparison. Automatic control disconnected.

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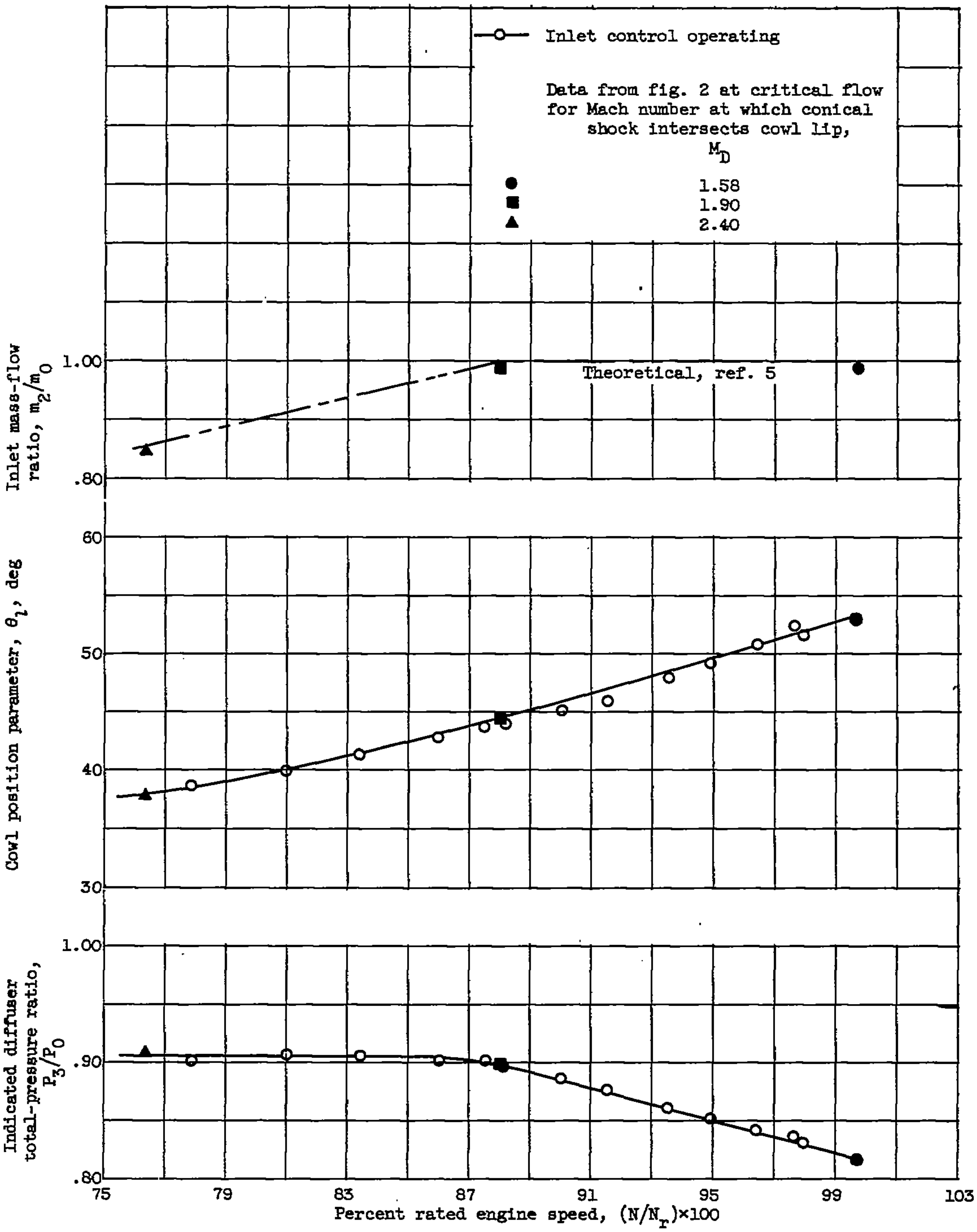

Figure 6. - Critical control by automatic spike translation. Mach 1.9; bypass fully open.

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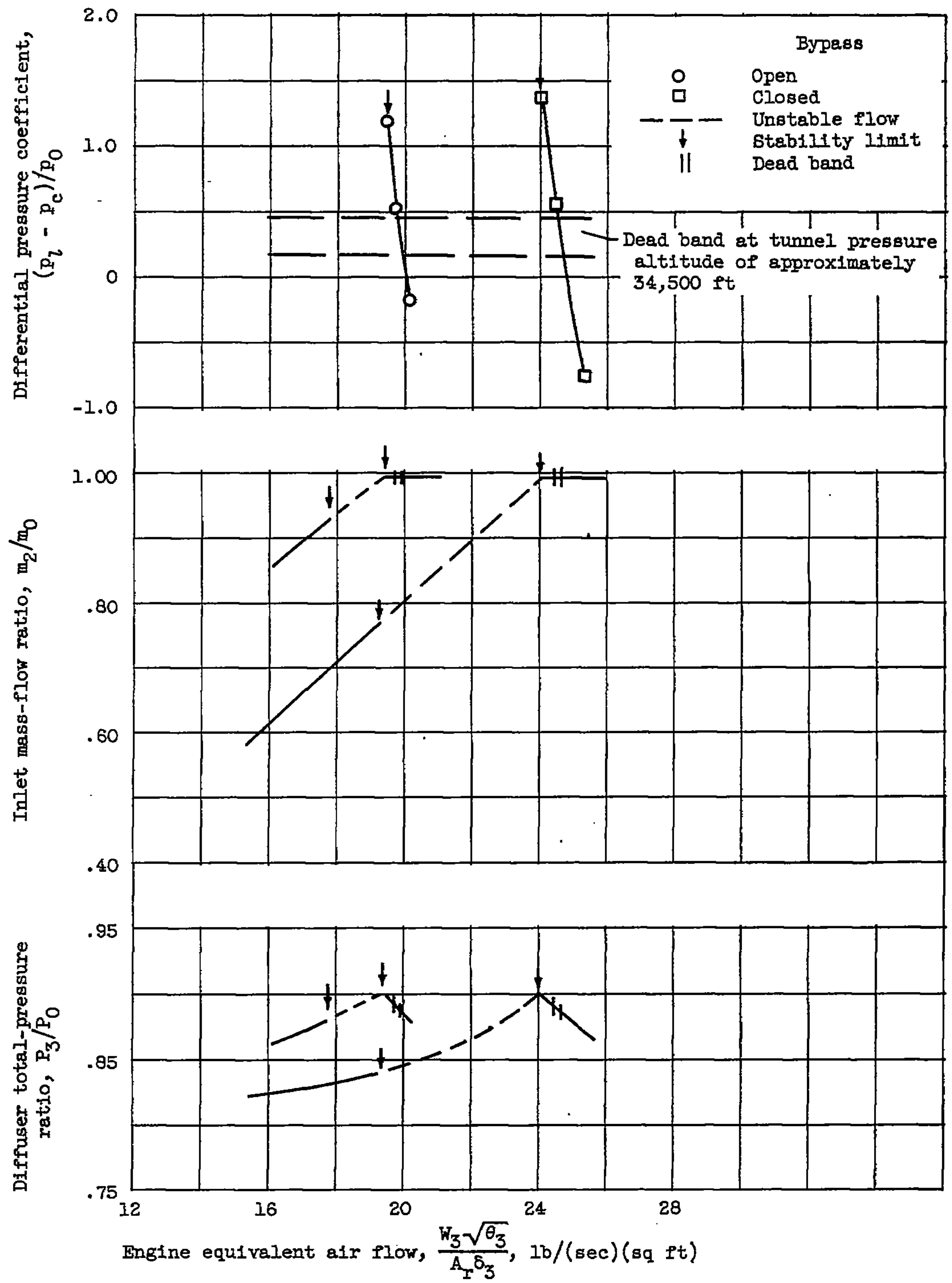

Figure 7. - Effect of bypass position on control pressures at Mach 1.9. Faired curves of figure 3 included for comparison. Mach number at which conical shock intersects cowl lip M_D equal to free-stream Mach number M_0. Automatic control disconnected.

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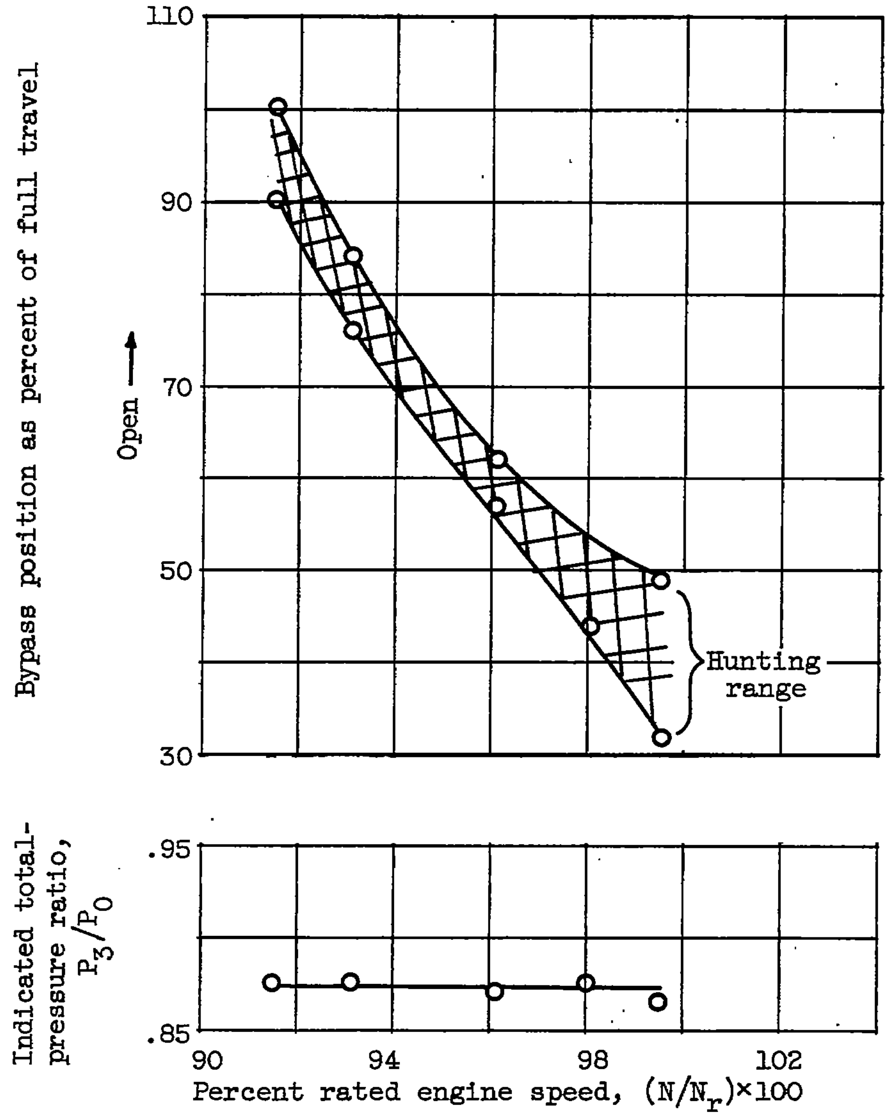
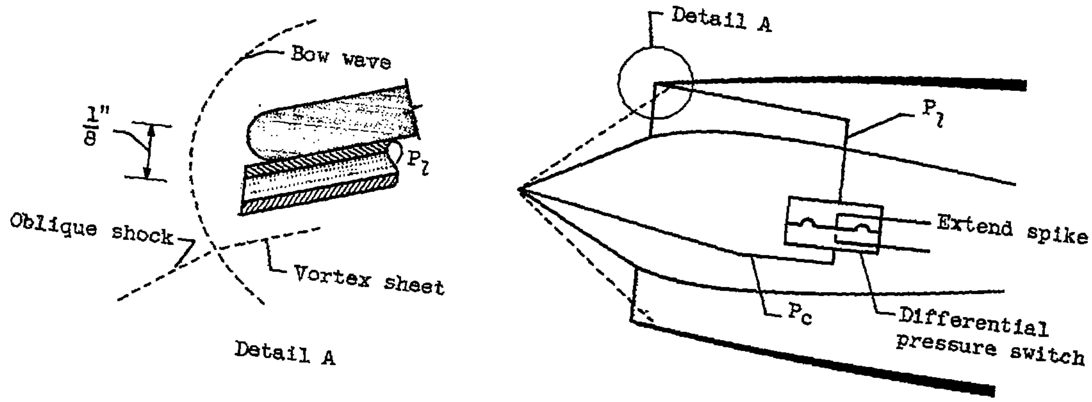
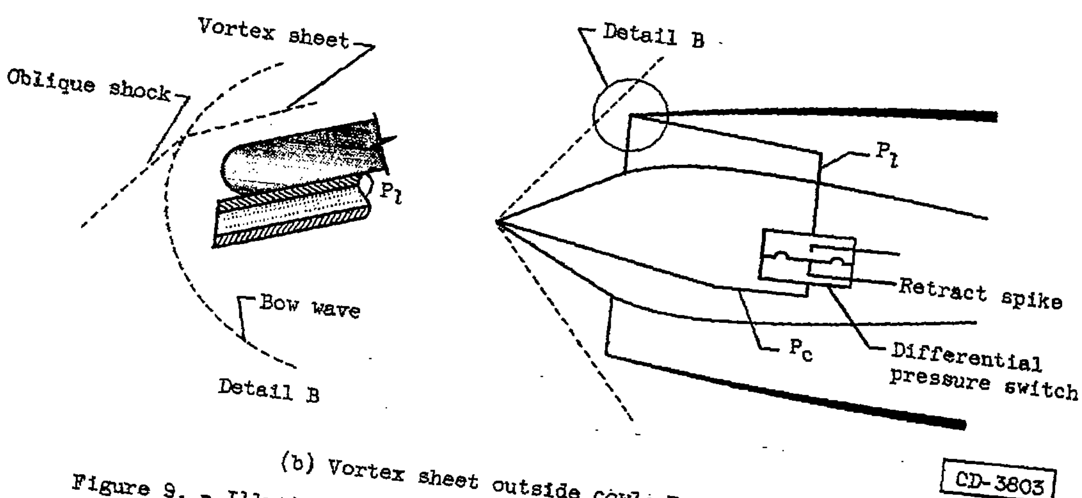


Figure 8. - Bypass automatically controlled by terminal-shock position. Operation at Mach 1.9; cowl position parameter, θ_l, 45.8°.



(a) Vortex sheet inside cowl; $P_c \approx P_l$.



(b) Vortex sheet outside cowl; $P_c < P_l$.

Figure 9. - Illustration of control designed to position oblique shock.

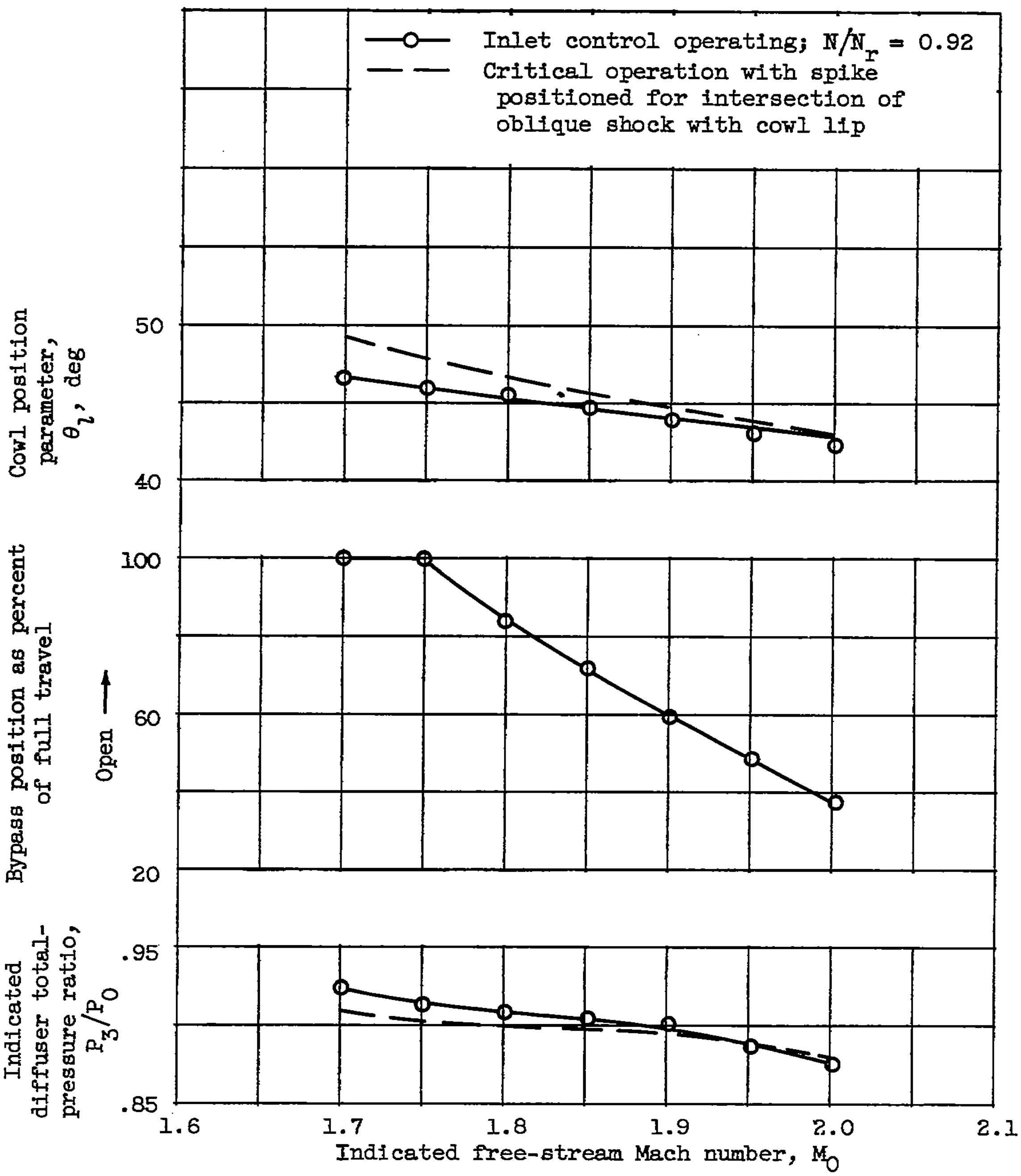


Figure 10. - Performance of combined control.